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22 March 1965

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TO: [redacted]

FROM:

SUBJECT: Proposed Continuation of Photointerpreter Response Research

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During the last fourteen months a series[1-3] of photointerpreter response studies have been performed. In addition to the technical results obtained from this work, a number of other items have been learned which form the basis of three conclusions which warrant consideration in future work. It is concluded that the proper experimental design and detailed procedures necessary in research of this nature dictate that such research should be performed on a longer-term basis. Because an experiment of good quality, yielding useful results, requires considerable time-consumption, it is also concluded that future studies should be directed at answering the most important and pressing questions. Finally, it is concluded that, whenever necessary, the scope of problems investigated should be sufficiently limited to enable a thorough study to be performed, i.e., one which yields useful data.

Discussions[4] held with representatives of NPIC and DD/S&T and a review of possible study objectives led to the conclusion that PI response as a function of ground resolution should be investigated. Results from such a study will assist in the planning for future systems by describing the intelligence yield as a function of system characteristics, cost and complexity.

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Several documents[5] dealing with present and future aerial reconnaissance requirements, discussions with intelligence analysts[6] and representatives of DD/S&T[6], and COMOR requirements indicate that targets related to missile development and deployment are, and are expected to remain, of greatest concern. Thus it was concluded that future PI performance should be studied using deployed missile sites, missile sites under construction, and missile and missile-engine test facilities. It was noted that Titan and Minutemen sites most closely resemble those targets of interest. These same discussions and documents revealed that insight into the accuracy of target mensuration as a function of ground resolution is urgently needed and should be a topic for investigation.

Discussions held regarding plans for future research also indicated that, since such research will deal primarily with detailed photointerpretation as opposed to scanning or searching, stereo photography should be used in the investigations. It was concluded that the ground resolution of primary interest ranges from present average capabilities down to near the theoretically-obtainable limit, i.e., from eight feet to eight inches.

In consideration of the above mentioned conclusions, it is suggested that we perform two studies: One dealing with photointerpretation and one dealing with mensuration. Specifically, the studies we propose are as described below:

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PHOTOINTERPRETER RESPONSE STUDY

OBJECTIVES:

1. To determine, as a function of ground resolution, the effect of PI performance on the usefulness of photography (of missile sites) in the analysis performed by intelligence analysts.

2. To determine validity of PI judgements of value of photography.

EXPERIMENTAL PARAMETERS:

Photography Type: Stereo black & white

Ground Resolution Range: [redacted] 25X1

Target Types:

1. Deployed missile sites
2. Deployed missile sites under construction
3. Missile test facilities

ANTICIPATED EXPERIMENTAL RESULTS:

A. For deployed missile sites, constructed or under construction:

The experimental procedure will be designed, to the greatest extent possible, to determine the ability of intelligence analysts to correctly answer four major questions from responses of PI's working with photography of various ground resolutions. These questions[7] are:

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1. Is this, or is this not, a silo?
2. What is the site's overpressure capability?
3. What is the site's reaction time?
4. Which weapon system is deployed or about to be deployed at this site?

Questions regarding specific capabilities of the deployed missile itself are best answered from non-photographic sources. Therefore questions will only be asked regarding site characteristics. Likewise, no regard will be given to electronics associated with missile sites since knowledge regarding electronics is not important as related to offensive weapons. (Electronics are, however, important as related to defensive missile systems).

B. For missile and engine test sites:

The experimental procedure will be designed to determine the ability of intelligence analysts to correctly determine the missile and/or the engine characteristics from responses[8] of PI's working with photography of various ground resolutions.

C. Incorporated into the experiment will be a procedure which will determine the correlation between actual PI performance and the worth of photography as judged by PI's.

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GENERAL EXPERIMENTAL PROCEDURE:

Although the experimental procedure has not yet been defined in detail, the general procedure is anticipated to be as follows:

1. Photograph about 5 deployed missile sites, about 3 deployed missile sites under construction, and about 5 missile test sites, using a frame camera at low altitude to obtain at least [redacted] 25X1 black and white, stereo pictures.

2. Make GEMS (photographs with simulated image-quality characteristics) of the approximately 13 stereo pairs. Since the low altitude required for resolution results in small terrain coverage per frame, photographic coverage of one site may consist of several frames. Also, the object height to camera altitude ratio will not be that obtained in real photography, but the difference will be negligible.

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3. With sufficient pre-testing, groups of PI's will be asked to perform tasks[7,8] with the GEMS.

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4. With sufficient pre-testing, another group of PI's will then be asked to judge the value of the [redacted] 25X1
[redacted] In the case 25X1
25X1 of the [redacted] ground resolution pictures, the [redacted] 25X1
picture will be shown and used as a benchmark having a judgement value of 100 while the [redacted] picture 25X1
will be assigned a 0 value. This procedure will then be repeated with the [redacted] feet ground resolution 25X1
pictures, using the [redacted] 25X1
pictures respectively as judgement value benchmarks.

5. The PI responses obtained from item 3 above will then be evaluated by intelligence analysts and from such analysis the usefulness of the various ground resolution determined.

6. The correlation of the PI responses obtained from item 4 above with the responses from item 3 above will then be determined, which should indicate the validity of value judgements made by PI's.

MENSURATION STUDY

OBJECTIVE: To determine the accuracy of target mensuration as a function of ground resolution.

The accuracy of target mensuration is primarily a function of the precision with which a hairline can be positioned on an image-edge

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and a knowledge of the picture-taking geometry. The accuracy of geometrical aspects have been previously examined. Thus this study will deal with the positioning of a hairline on image-edges.

It was concluded that stimuli for this study should be prepared in the laboratory and should consist of a variety of geometrical shapes of various contrasts relative to the background. Samples of each of the geometrical patterns would have different edge gradients, where the shape of the edge gradient corresponds to the shape of the simulated modulation transfer function and the size or extent of the edge gradient corresponds to simulated ground resolution.

It is suggested that this study be separate from the photointerpreter response study. This study does not require PI subjects and can be performed on its own schedule.

ANTICIPATED EXPERIMENTAL RESULTS:

The experimental procedure will be designed so that the data obtained will be applicable to edge-gradients of real photography. Hence, from a measurement of edge gradients of real material, the accuracy of mensuration of that material can be determined when combined with its image-forming geometry.

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Although the specific details of this proposed research have not yet been established, initial tasks have been considered and are shown on the next page.

Since this proposal is based on discussions with you and other members of NPIC, and since the initial effort will be similar regardless of subsequent activity, we plan to proceed at once with this work as described in this memorandum while looking to you and your staff for any changes which you consider desirable to incorporate into the research plans.

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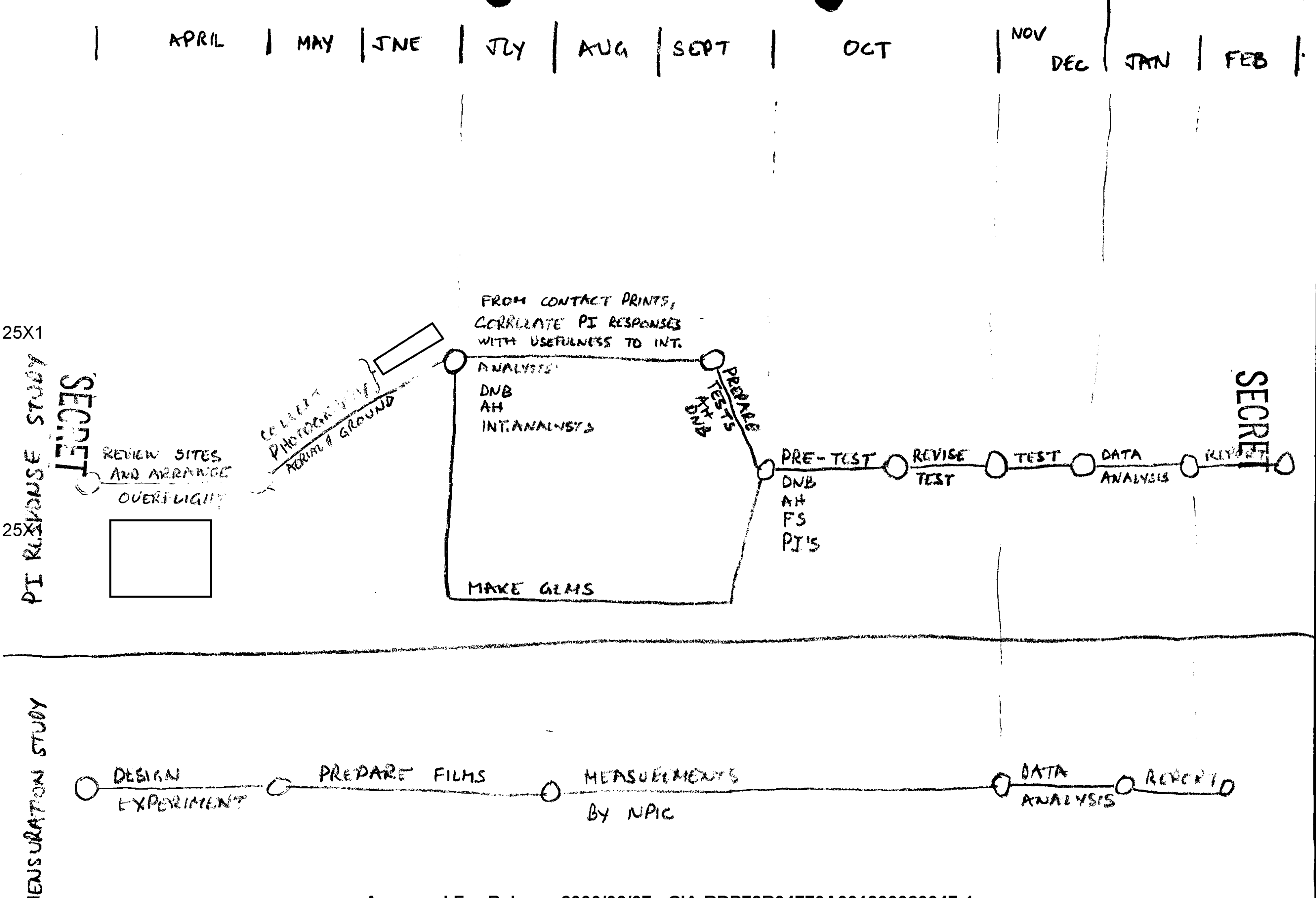
SCHEDULE: PHOTO INTERPRETER RESPONSE STUDY



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REFERENCES

1. A Study of Photographic-Image Recognition as a Function of Ground Resolution. 21 Feb 64.

2. Aircraft Image Analysis as a Function of Photographic Ground Resolution. Dec 1964.

3. The Effects of Stereo Convergence and Obliquity Angles on the Judged Worth of Aerial Photographs. March 1965.

4. One discussion occurred on 17 Dec 1964 after a briefing in which the results of a study (reference 2, above) were presented. Discussion participants at this meeting included:

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[redacted]

The second major discussion was held on 9 Jan 1965 at NPIC. The purpose of this meeting was to discuss the goals of future PI response studies. It was generally concluded that after completion of the study given in reference 3 above, a more thorough study should be performed over a longer time period.

Those present at this meeting included:

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REFERENCES (continued)

5. Specific references not given here for security reasons.

6. Intelligence analysts: Messrs. [redacted] 25X1
25X1 [redacted].

DD/S&T representatives: [redacted] 25X1

7. The four major questions asked of the intelligence analysts and the PI tasks requested by the intelligence analysts are listed below:

Int. Analyst Question	PI Task (Not a complete list; rather, it is indicative of typical PI tasks.)
1. Is this, or is this not, a silo?	Detailed examination
2. What is site's overpressure capability?	Determine: a. Silo diameter b. How is silo made c. Thickness and geometry of site's structures d. Amount of steel & concrete in structures e. Are silo cover edges straight or bevelled f. How are structures of site connected g. Do tunnels have "Universal Joints" h. Etc.
3. What is site's reaction time?	Determine: a. Does missile fly out or lift out b. Are there propellant tanks c. Is propellant cryogenic or storable, liquid or solid d. Etc.
4. Which weapon system is deployed or about to be deployed at this site?	Determine: a. Silo diameter b. Evidence of exhaust ports c. Etc.

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REFERENCES (continued)

8. The following PI tasks are typical of those from which the intelligence analyst can determine missile or engine characteristics:

   a. Is missile or engine horizontal or vertical?

   b. Is site dormant or active?

   c. Is site wet or dry?

   d. Size, shape and type of blast deflectors.

   e. Size, geometry and similar construction details.

   f. Number of stages.

   g. Piping characteristics and presence of adjacent tanks.

   h. Liquid or solid fuel.

   i. Flow capacity of plumbing.

   j. For storable liquid: What is tank size, for oxidizer to fuel ratio determination?

   k. Type of ejector equipment: For sea level or altitude experiments?

   l. Is liquid oxygen manufactured near by?

   m. Layout of buildings--is this an explosive area--do buildings have blow-out provisions?

   n. For buildings under construction: Is missile or engine vertical or horizontal during manufacture? During moving? During storage?

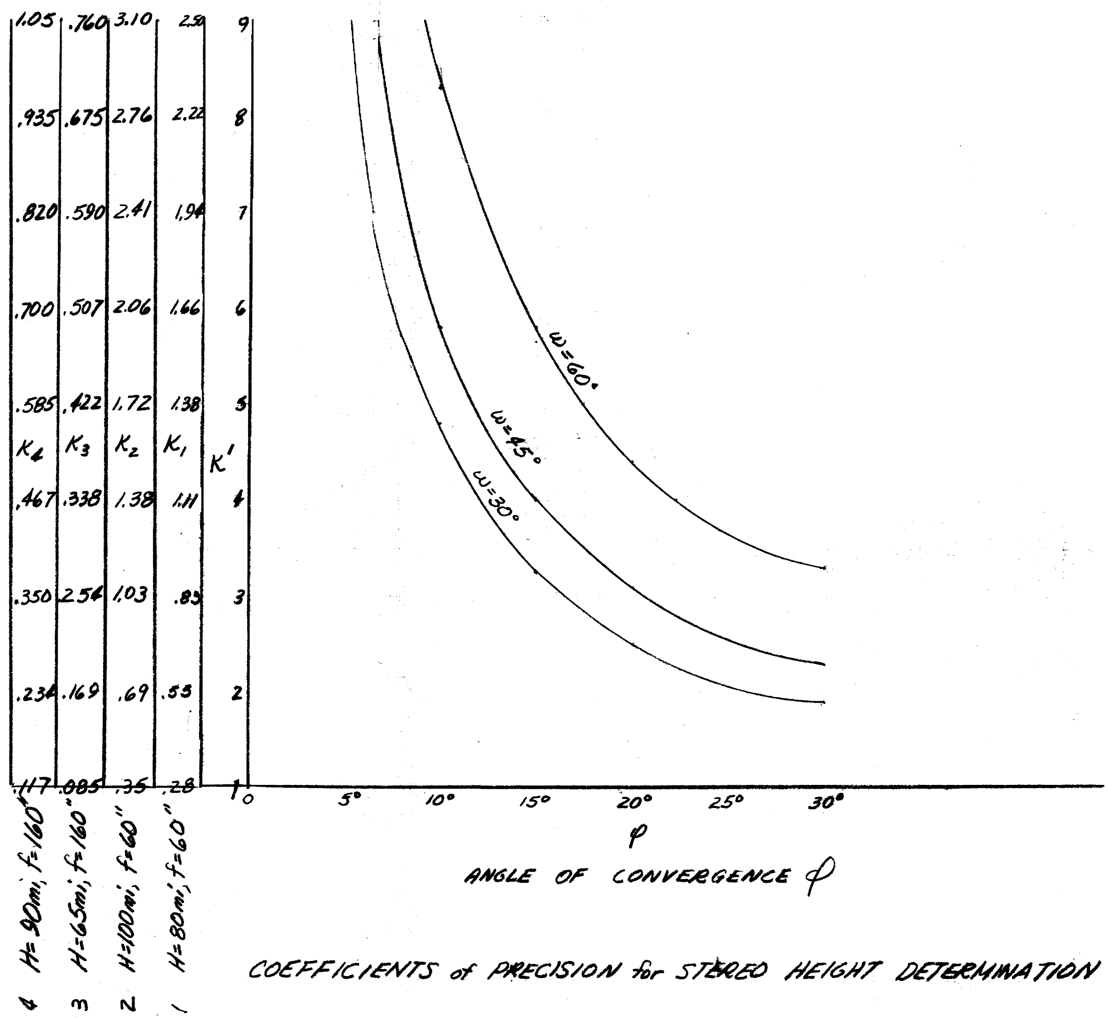
   o. Layout of rail lines--size of rails.

   p. Is this experimental or production test stand?

   q. Size of doors of drive-through buildings.

   r. Type of engine.

   Items h, k and r are three most important tasks.



COEFFICIENTS of PRECISION for STEREO HEIGHT DETERMINATION

The Effect of Angles of Convergence and Obliquity on the Stereoscopic Determination of Height

The accuracy with which stereoscopic heights may be determined is a function of three parameters: (1) the scale of the imagery, (2) the base-height ratio, and (3) the measuring precision or resolution of the imagery. For vertical photography this functional relationship may be expressed by the equation (Doyle, 1963)

$$m_h = \frac{H}{f}\frac{H}{B} m_x \sqrt{2} \qquad (1)$$

where

m_h is the precision with which a stereo height may be determined,

H/f is the inverse of the photograph scale,

H/B is the inverse of the base-height ratio,

m_x is the precision with which parallax may be measured on the particular photography, and

$\sqrt{2}$ provides for the fact that two photographs are involved.

The base-height ratio can be expressed in terms of the angle of convergence (pitch angle), φ, as

$$\frac{B}{H} = 2 \tan \varphi. \qquad (2)$$

The base-height ratio is unaffected by the angle of obliquity.

The scale of the photography is affected by both the angle of convergence and the angle of obliquity. At the center of the model, the scale (in the direction of flight) will be

$$\text{Scale} = \frac{f}{H} \cos^2\varphi \qquad (3)$$

for a convergent photograph without obliquity. If the oblique angle (roll angle), ω, is introduced, the scale becomes

$$\text{Scale} = \frac{f}{H} \cos^2\varphi \cos\omega. \qquad (4)$$

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17 Dec 64

...ations (4) and (2) may be substituted in equation (1), which leads ... expression

$$m_h = \frac{H}{f}\,\frac{1}{2\cos^2\varphi\,\tan\varphi\,\cos\omega}\,m_x\sqrt{2} \qquad (5)$$

...

$$m_h = \frac{H}{f}\,\frac{1}{\sin 2\varphi\,\cos\omega}\,m_x\sqrt{2} = \frac{H}{f}\,K'\,m_x \qquad K' = \frac{\sqrt{2}}{\sin 2\varphi\,\cos\varphi} \qquad (6)$$

Finally, for a flying height, H, of 550,000 feet and a focal length, f, of 77 inches, the expression for the precision of stereoscopic height determination becomes

$$m_h = \frac{0.4}{\sin 2\varphi\,\cos\omega}\,m_x = K\,m_x \qquad \frac{550000\,ft\,\sqrt{2}}{77\,in\;25.4(10^3)\frac{\mu}{in}} \qquad (7)$$

where ... is in feet and m_x is in microns.

The graph, Figure 1, shows a plot of the coefficients K (equation 7) and ... equation 6) as functions of the angle of convergence, φ, and the angle of obliquity, ω. To find the coefficients of relative precision ... for a particular configuration, enter the graph at the bottom ... the angle of convergence, φ; proceed upward to the angle of obliquity, ..., and then proceed to the left to the proper coefficient.

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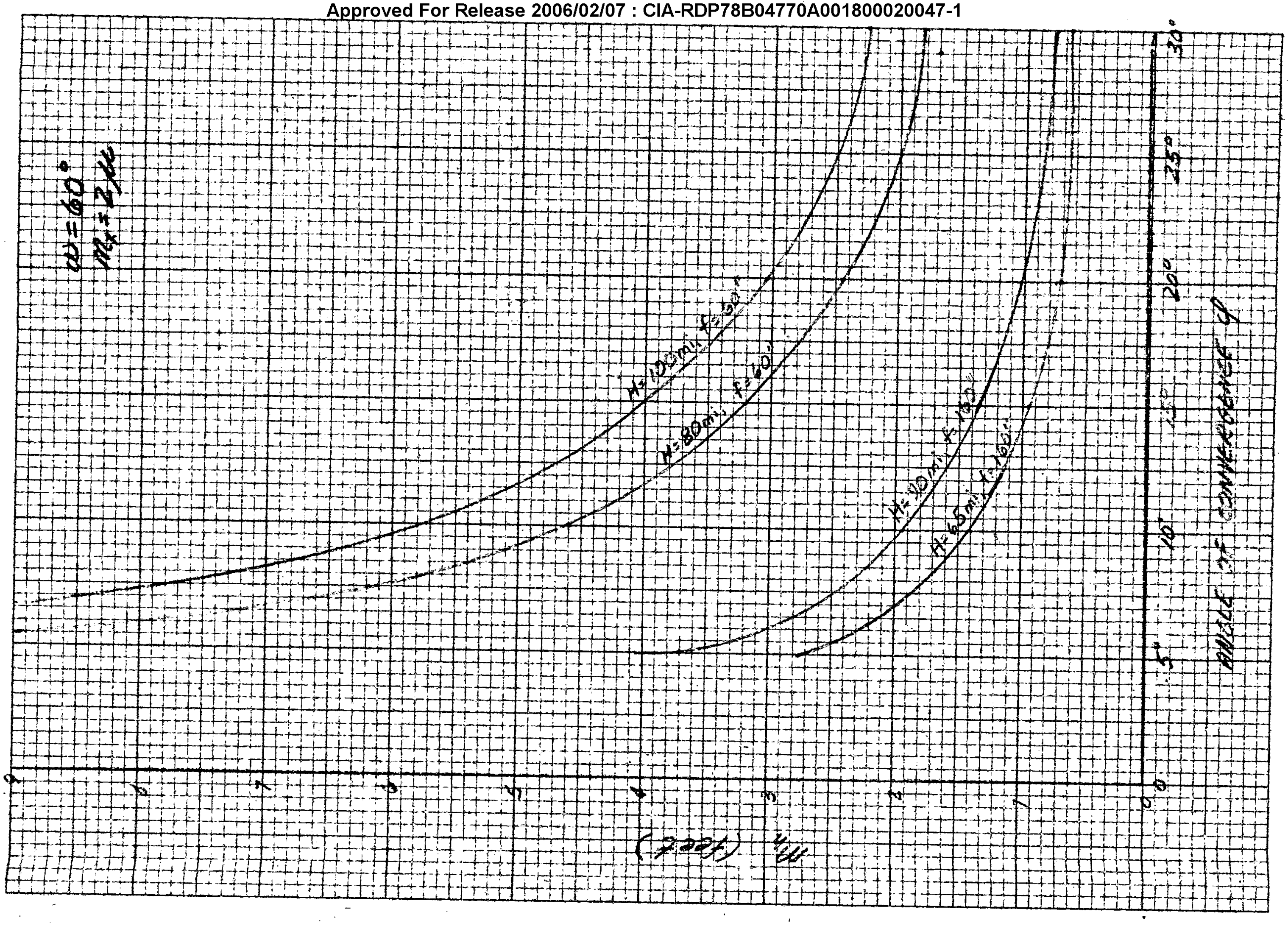
ω=60°
H=100mi f=60"
H=80mi f=60"
H=100mi f=150"
ANGLE OF CONVERGENCE φ

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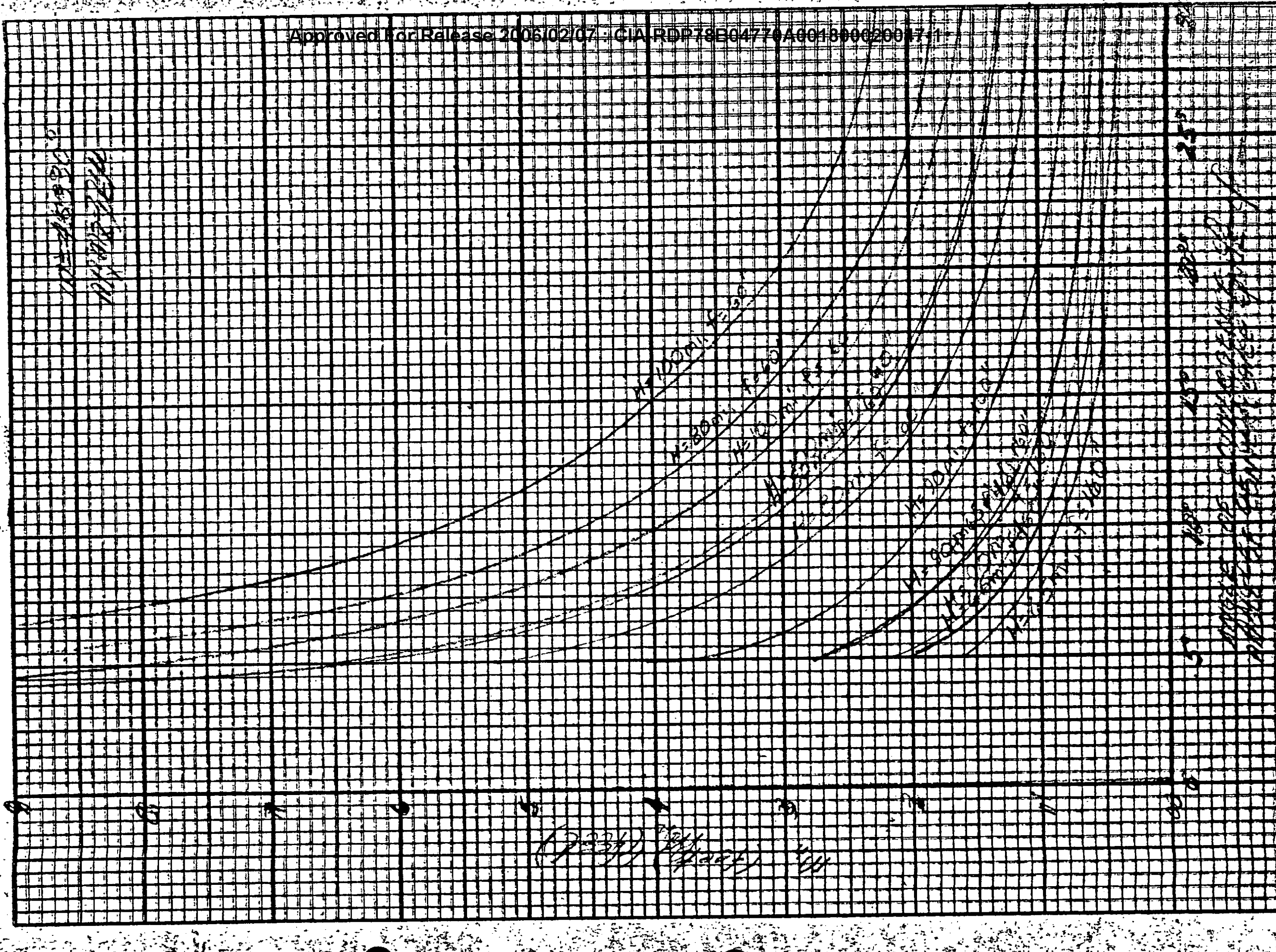

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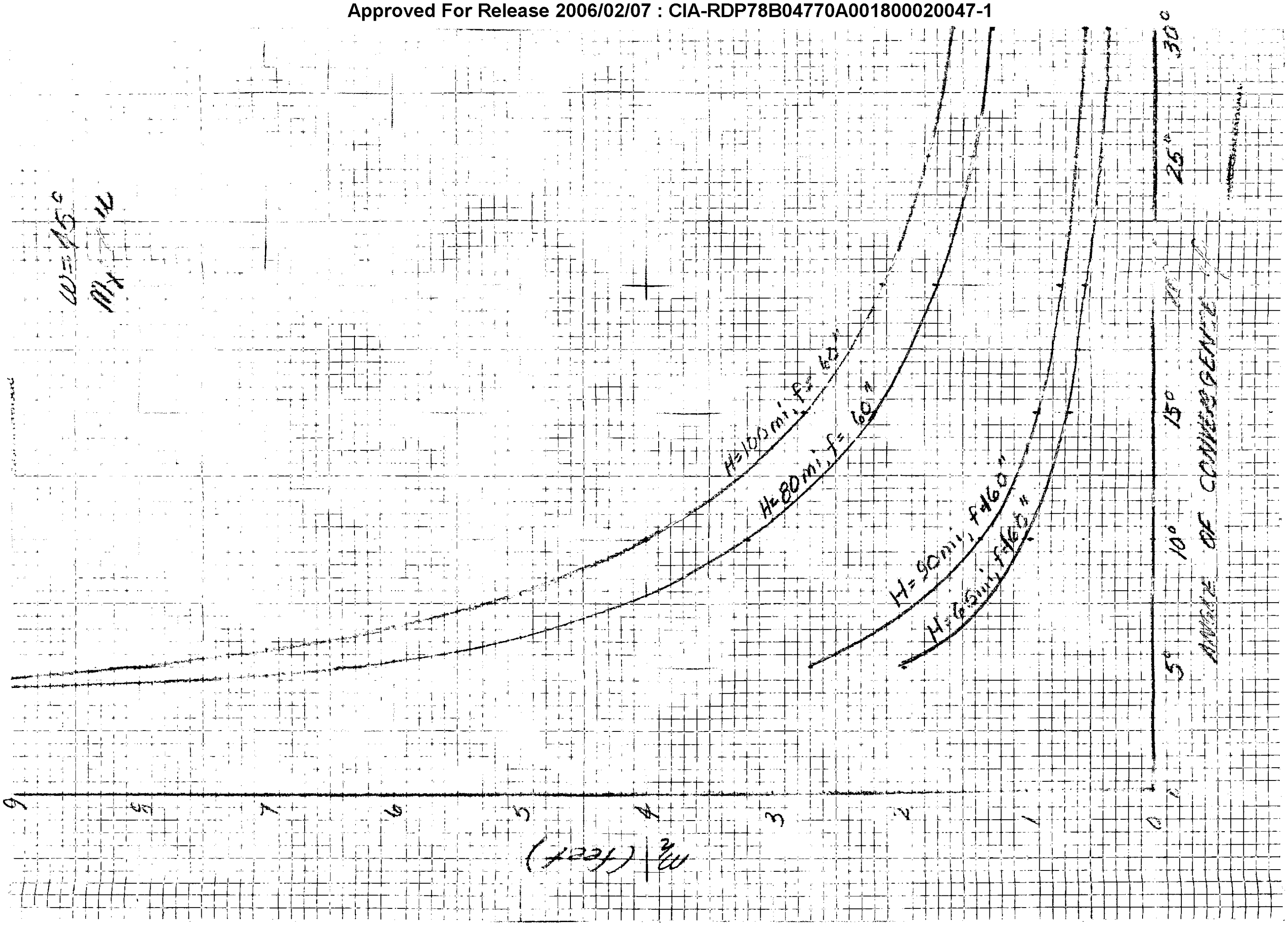

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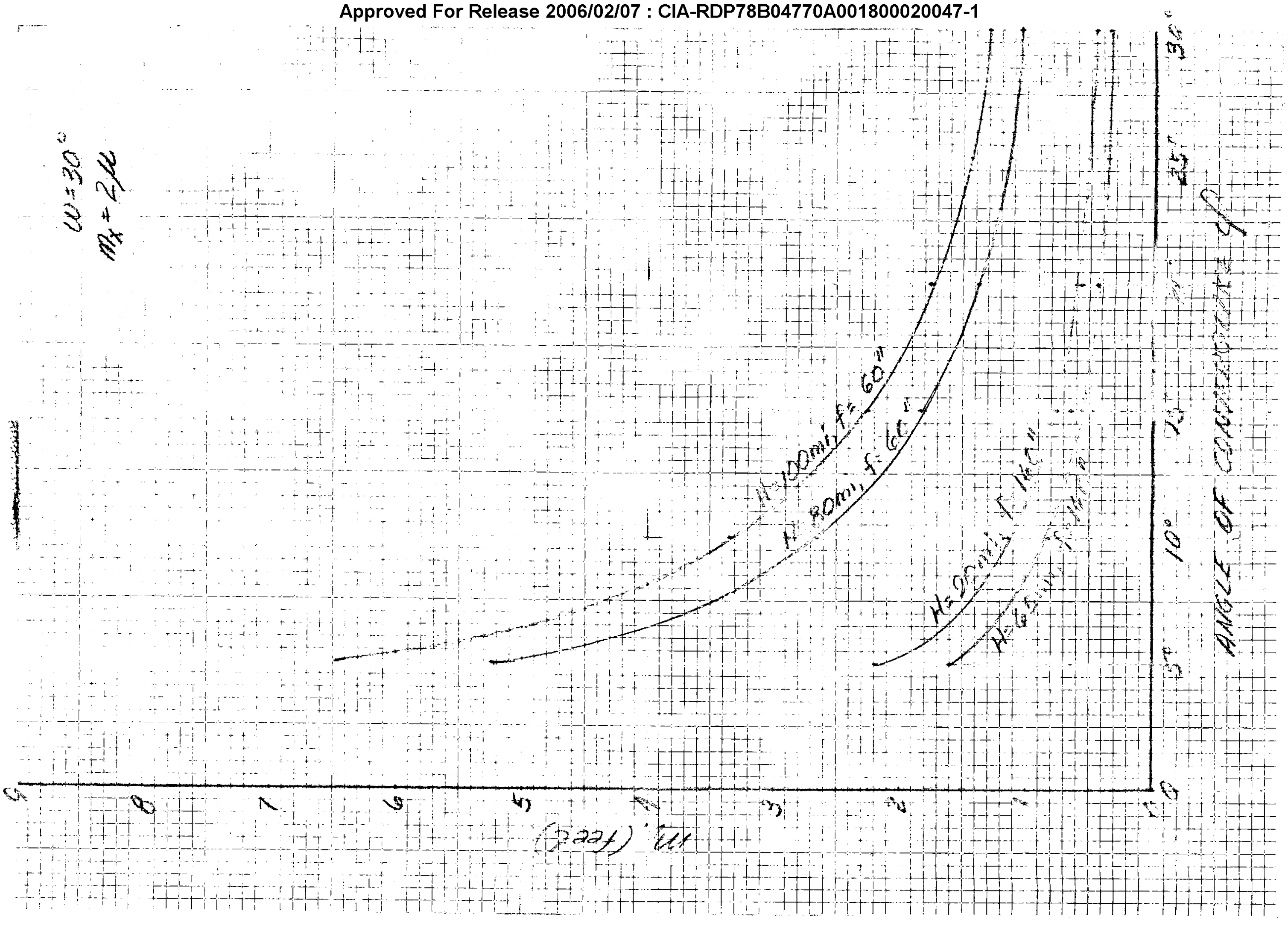

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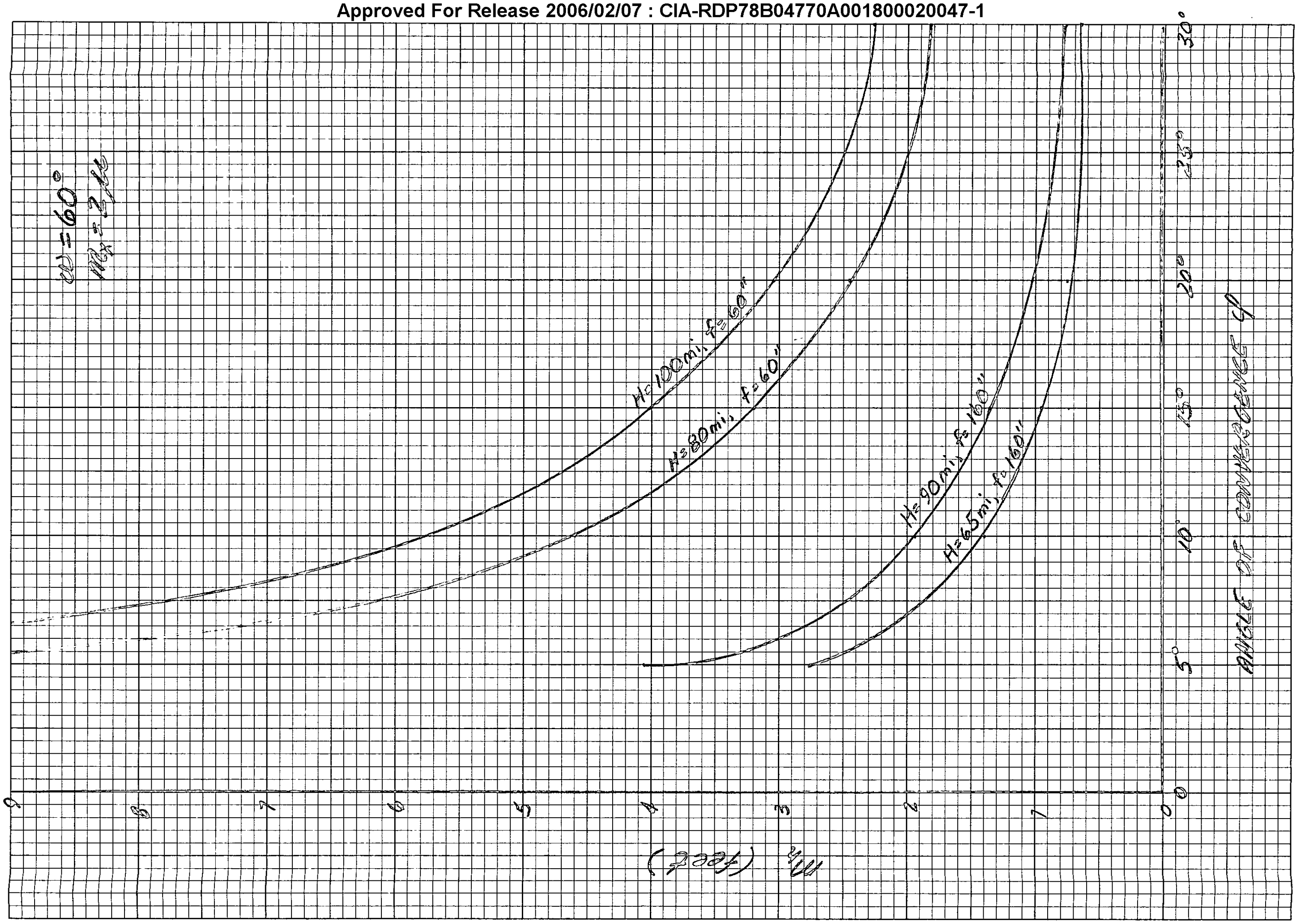

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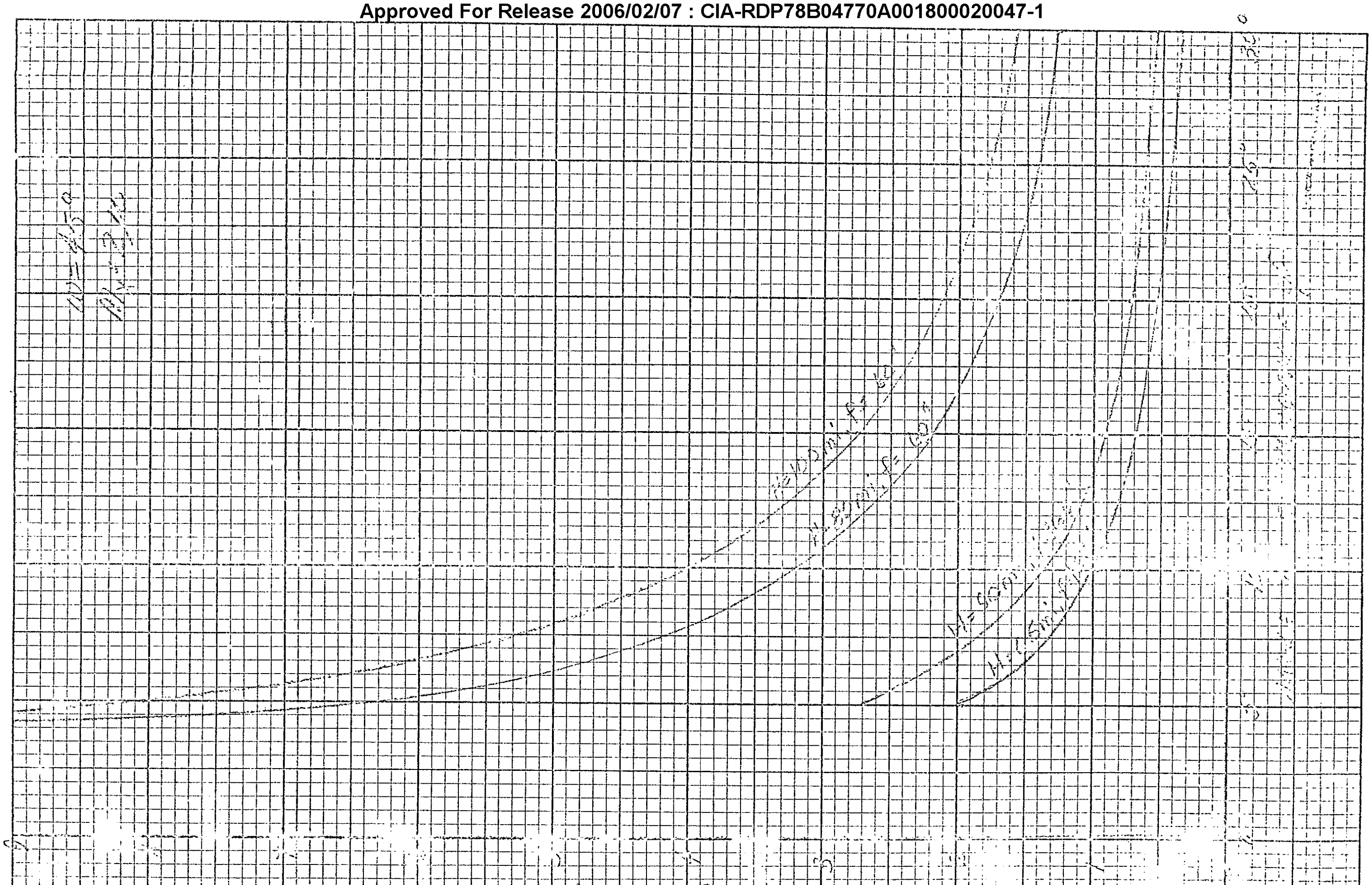

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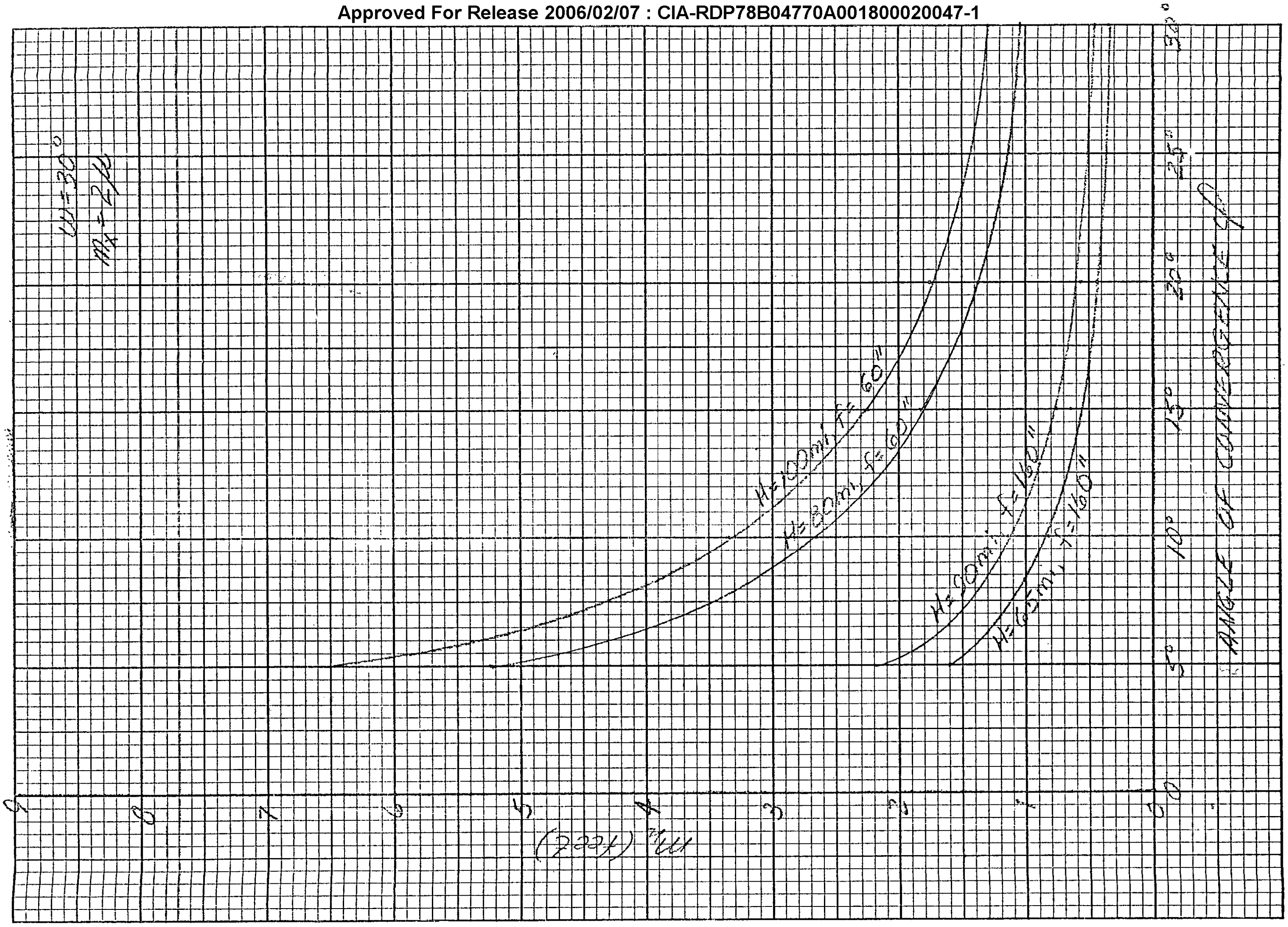

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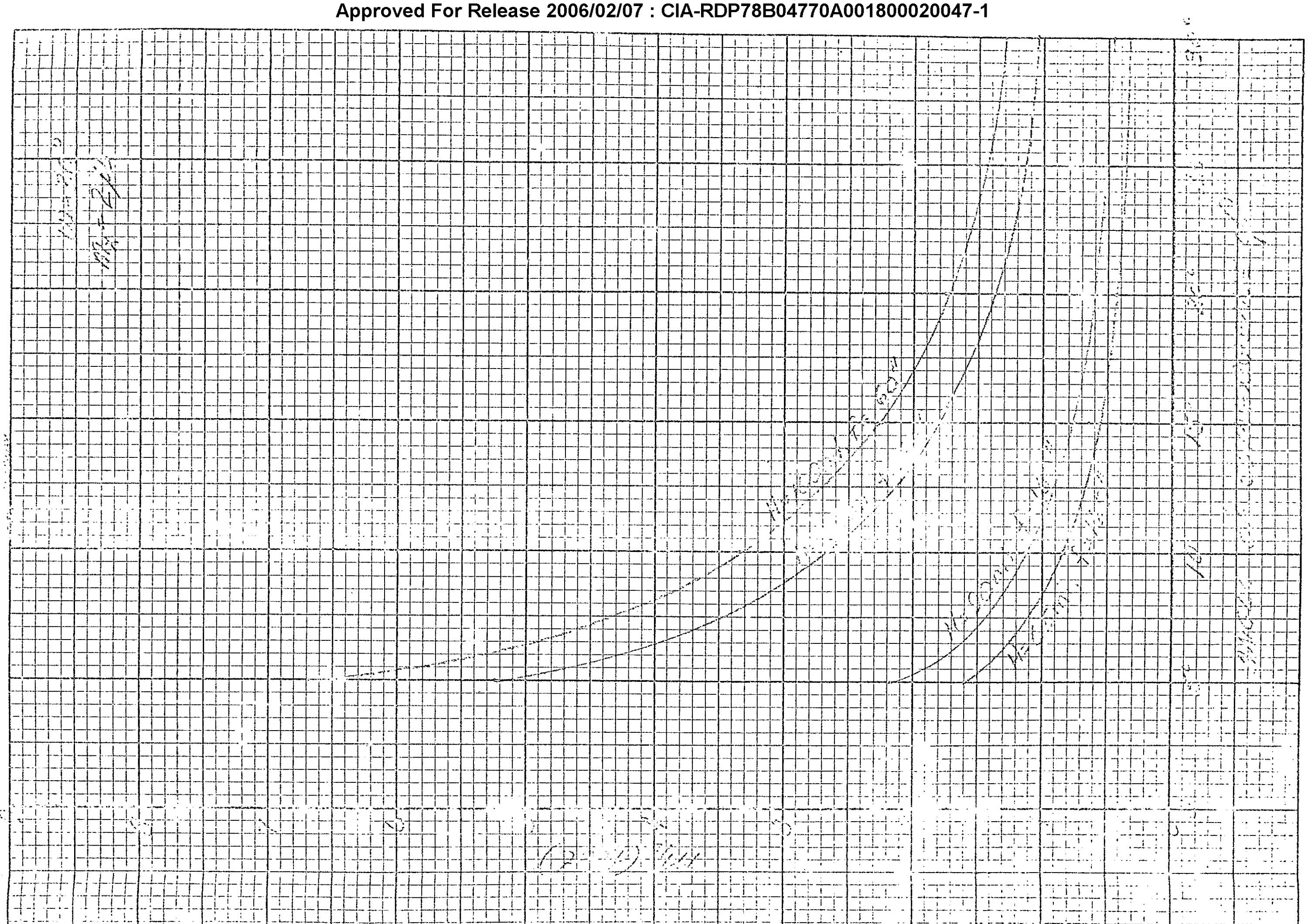

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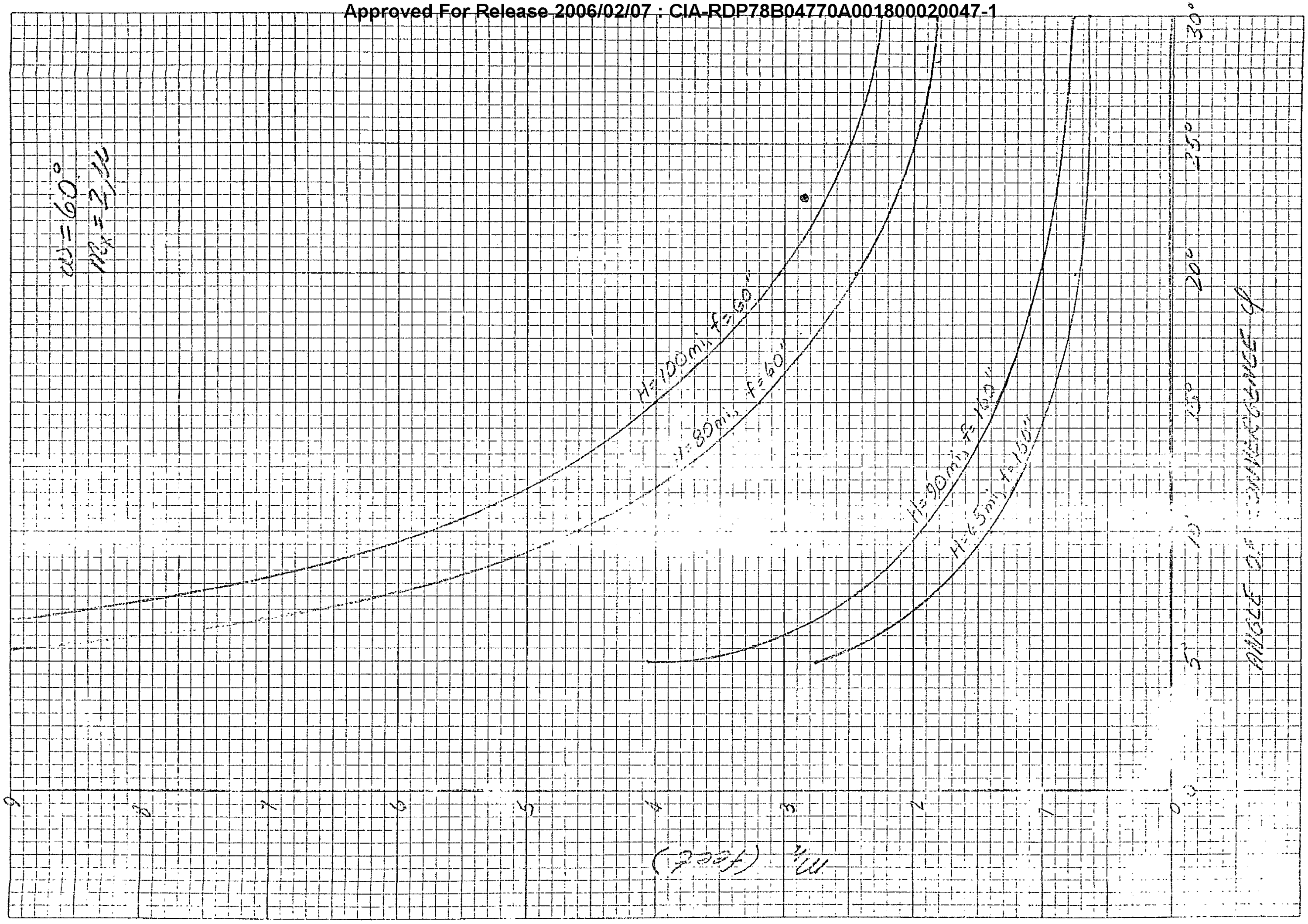

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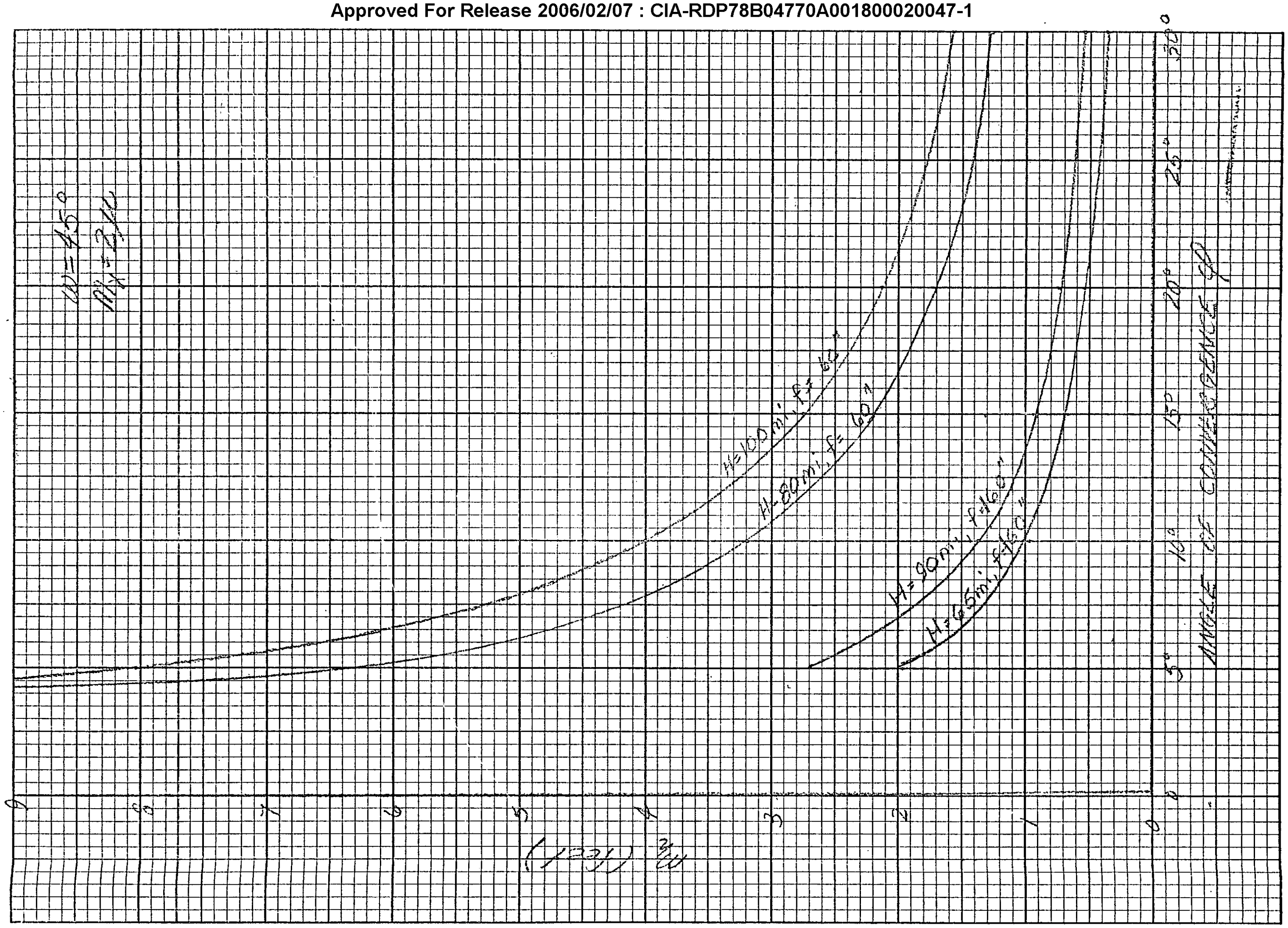

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